Effect of Mixing Process on Microleakage of Glass Ionomer Cements Used in Atraumatic Restorative Treatment on Primary Molars

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Aiming to assess the effect of mixing process on microleakage, 40 primary molars were filled with encapsulated glass ionomer cements (GICs) (Vidrion,RCaps and Fuji,IXGPFAST) or with GICs stored in bottles (Vidrion,R and Fuji,IX). Dye penetration was assessed using scores. Encapsulation and mechanical mixing have reduced significantly marginal microleakage levels in class II restorations performed with conventional GICs if compared to the values obtained by their bottled correspondents (p=0,000).
Key words: *Atraumatic restorative treatment, glass ionomer, mixing, encapsulate and pre-dose*
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INTRODUCTION

The glass ionomer cements (GICs) are widely indicated in modern dentistry, especially in the Atraumatic Restorative Treatment (ART) and in Pediatric Dentistry.[1-3]

The Atraumatic Restorative Treatment is a new proposal of dental care that tries to control the development of the carious lesion, helping the organism to react against the assault of cariogenic bacteria. It basically consists of partial removal of the carious lesions and subsequent filling of the cavities with the restorative material, in association with preventive and educational measures.[4]

The conventional restorative GIC are indicated to the ART both because its adhesion capacity and fluoride release properties and for its chemical set mechanism that exempts technological sophistication. These features make them very interesting materials either to traditional Pediatric Dentistry.

The high success rates reported with the use of ART in both permanent[4-7] and primary[8-10] teeth has boosted the adaptation of the initially proposed treatment to places without the proper infrastructure to the conditions conferred by traditional dentistry. The ideal was to make profit out technological resources in order to favor the human organism innate repairing capacity. It was then when the ART started to be used on a modified basis at dental offices, what allowed the use of a first choice material, with better formula and presentation form.

Some GIC suffered formulae alterations in order to meet better working conditions demanded by the ART: the setting time was decreased, they became less sensible to moisture, and their mechanical properties were improved so they became more resistant to occlusal wear. Nevertheless, even the new GICs developed to ART are still very technique sensitive. The adequate proportion between powder and liquid and the proper mixing technique are essential to reveal the good properties of this material and, at the same time, to minimize its deficiencies.[11]

The difficulty in obtaining the right powder / liquid proportion when the cements are in separate bottles and the limitations of a manual mixing technique have leaded to a commercial availability of the encapsulated and pre-dosed GICs. This presentation requires mechanical mixing, once the separating membrane between the powder and the liquid is ruptured.[12] The encapsulated GIC, less likely to be used in the field due to the need of electric power in order to be mixed, becomes an interesting option to the office environment, since the mechanical mixer is exactly the same one used for mixing many other pre-dosed and encapsulated materials, such as silver amalgam.

The encapsulated GICs have the advantage of maintaining the fixed powder/liquid proportion recommended by the manufacturer, optimizing the material properties.[2,13-15] The mechanical mixing guarantee a consistent and effective mixing of the cement powder with the liquid.[2,16] Generally speaking, there has been an

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improvement in the encapsulated GIC properties when compared to the ones available in separate bottles.[11,13-18]

This work aimed to assess the effect of the mixing technique of two conventional restorative GICs used with the ART approach on microleakage of deciduous molars class II restorations in an *in vitro* environment.

METHODS AND MATERIALS

The "Committee of Ethics in Research of the Federal University of Minas Gerais" approved this experimental protocol.

Forty clinically sound second primary molars extracted for orthodontic reasons or naturally exfoliated, stored in distilled water, were used in this research, with the children's and their families illustrious consent.

Two class II cavity preparations, vertical box type, were performed in every tooth (mesial and distal), standardized by the following parameters: 2 mm width, 2 mm depth – determined by the bur diameter (cylinder diamond bur with round tip 4230 Microdont,) – and high enough to leave the gingival wall 1mm above the cement/enamel limit. The bur was used in a high-speed hand piece, under air and water refrigeration and was replaced after every five preps. The cavity finishing was performed with the same diamond bur in a low speed hand piece and manual instruments.

All teeth underwent a prophylaxis with pumice powder and distilled water with a Robinson® brush and then were rinsed and dried.

After a simple draft, 20 of the 80 cavities were restored with each material: Vidrion R,, Fuji, IX (GIC stored in separate bottles), Vidrion, RCaps and Fuji, IXGPFAST (encapsulated GIC).

The restorative procedures were performed by a single operator in a room 23°C ±2°C, according to the manufacturer's instructions.

A dentin conditioner (Vidrion, dentin conditioner for Vidrion R,and Vidrion, RCaps, Fuji, IX liquid itself for Fuji, IX, GC® Cavity Conditioner for Fuji, IXGPFAST) was applied over the surface of the cavity with a disposable brush for 30 seconds. After that, the cavity was rinsed for three times with a moist cotton pellet and dried with another cotton pellet.

After a stainless steel band had been adapted to the tooth, the materials were manipulated and inserted in agreement with the manufacturers' instructions. A high frequency mechanical mixer CAPMIX® (ESPE) was used to mix the capsules. The GIC were inserted in the cavities still presenting shine, each one at its time, with the help of a blunt Hollenback instrument (Duflex) for the GIC stored in separate bottles and been direct exerted through the capsule for the Fuji, IXGPFAST. To create similar conditions to the Fuji, IXGPFAST insertion mode, also because Vidrion, RCaps has no device to allow direct extrusion of the material into the cavity, a tip of Centrix, syringe (Centrix Inc.) were used with this material. As soon as the cement started to loose its shiny appearance, pressure was applied for 30 seconds with an amalgam packer, lubricated with petrol jelly (Vaseline).

Fifteen minutes after the filling with the second restorative material, the band was cut and the GIC excesses were removed with an adapted scalpel blade. After that, a layer of Vidrion, V was applied over the restorations of Vidrion R,and Vidrion, RCaps while a layer of Fuji, Varnish covered the restorations of Fuji, IX and Fuji, IXGPFAST. The polishing procedures were performed after an interval of 24 hours with flexible sand paper discs (Sof-Lex®/3M), after which a new layer of varnish was applied.

The materials used to perform the restorations, as well as their respective manufacturer's, batches, features and mixing methods are represented in Table 1.

Table 1: Materials, respective manufacturers, batches, features and mixing methods

Material	Manufacturer	Batch	Features	Mixing methods
Vidrion® dentin conditioner	SS White	OOA	Dentin conditioner	___________
Vidrion® R	SS White	OPU/OPA	Conventional restorative GIC	Manual
Vidrion® R_{Caps}	SS White	OOE	Conventional restorative GIC	Mechanical
Vidrion® V	SS White	OOE	Protector varnish	___________
GC® Cavity Conditioner	GC Corporation	103221	Dentin conditioner	___________
GC Fuji® IX	GC Corporation	107041	Conventional restorative GIC	Manual
GC Fuji® IX_{GPFAST}	GC Corporation	9910263	Conventional restorative GIC	Mechanical
Fuji® Varnish	GC Corporation	106221	Protector varnish	___________

All teeth had their pulp chambers waterproofed with ultra fast set Araldite, epoxy resin and the remaining surfaces covered with two layers of cosmetic nail polish, always respecting 1 mm distance around the cervical margins of the restorations.

Twenty-four hours after the waterproofing, teeth were immersed in 0.5% methylene blue water solution (pH 7.2, at 37°C) for 4 hours, washed in running water and dried for 24 hours at room temperature. Teeth were then embedded in transparent polyester resin (Cristal).

The resin blocks with the teeth embedded were cut in the mesio distal aspect in a precision cutting machine (Isomet, 1000), with a 12.7 cm x 0.5 mm diamond disc (Buehler, series 15 HC diamond, n. 11.4215) under distilled water refrigeration. The cutting machine was set to 750-rpm speed and 250-gf loads.

The tooth section was meant to coincide with the very center of the restorations. Nevertheless, anatomical features inherent to primary teeth made it impossible to use a single cut all the times. The number of sections achieved for each tooth varied, and consequently, the number of cut to each group varied. This difference was due to fractures and losses of a few cuts during the sectioning of the teeth. All surfaces of each restoration obtained after cutting were assessed using a 30 X magnification light optical microscope through the score criteria.

Three calibrated examiners classified the gingival marginal dye penetration of the restorations according to the following scale, based upon the work of Yap et al.19: 0 = No dye penetration; 1 = Dye penetration up to half the extension of the cervical wall; 2 = Dye penetration beyond half up to the whole extension of the cervical wall; 3 = Dye penetration reaching the axial wall.

Each examiner performed all possible readings to each one of the test samples (1 test sample = 1, 2, 3 or 4 readings, depending on the surfaces made available by the cuts), unaware of the other examiners reading results. The total number of readings amounted to 450. Nonetheless, median values were used between examiners for each section, since the Kappa test revealed harmony among them (1x2 = 0.61; 1x3 = 0.71; 2x3 = 0.77), in such a way 150 results were obtained to assessment.

The Kruskall-Wallis non-parametric test was applied to compare the cervical leakage median scores obtained by the three examiners for each one of the dental sections (1st, 2nd, 3rd, or 4th section obtained by the cuttings), having no difference among them with regards to the percentage of maximum scores. In order to compare the cervical leakage median scores obtained for the different GIC mixing methods, the Mann-Whitney non-parametric test was used to independent small samples. The significance level of 5% was considered (p<0.05).

Table 2: Microleakage score frequency for each material (median values between examiners)

Microleakage scores	Mechanical mixing method				Manual mixing method			
	Vidrion RCaps		Fuji IXGPFAST		Vidrion R		Fuji IX	
	n	%	n	%	n	%	n	%
0	11	27.5	3	7.1	0	-	1	2.9
1	14	35.5	6	14.3	4	11.8	0	-
2	3	7.5	4	9.5	1	2.9	1	2.9
3	12	30.0	29	69.0	29	85.3	32	94.1
Total	40	100.0	42	100.0	34	100.0	34	100.0

Table 3: Microleakage score frequency for each mixing method (median values between examiners)

Microleakage scores	Mechanical		Manual		Total	
	n	%	n	%	n	%
0	14	17.1	1	1.5	15	10.0
1	20	24.4	4	5.9	24	16.0
2	7	8.5	2	2.9	9	6.0
3	41	50.0	61	89.7	102	68.0

Table 4: Mann-Whitney test results

Variable	Compared groups	p-value	Lower microleakage scores
Mixing method	(Fuji IX) x (Fuji IXGPFAST)	0.007	Mechanical
	(Vidrion R) x (Vidrion RCaps)	0.000	Mechanical
	[(Fuji IX) + (Vidrion R)] x [(Fuji IXGPFAST) + (VidrionRCaps)]	0.000	Mechanical

RESULTS

Table 2 presents the microleakage score frequency for each experimental condition. The material with better performance was Vidrion, RCaps (only 30% of the samples with severe microleakage and 62.5% of the samples with light or absence of leakage). The worst performance material was Fuji, IX (94.1% of the samples restored with this material presented severe microleakage).

Table 3 shows that the greater percentage of maximum scores (3) for cervical microleakage was found when using the manual mixing method (89.7% against 50% when using the mechanical mixing method).

When the materials were assessed as a group, it is correct to state that a highly significant difference was present (p=0.000) in the cervical microleakage scores between the manual mixing materials and the mechanical mixing ones, the last ones presenting the smaller values (Table 4).

When only Fuji, IX and Fuji, IXGPFAST were compared, the mechanically mixed one (Fuji, IXGPFAST) also presented cervical microleakage scores significantly lower (p=0.007) than the values presented by its manually mixed correspondent (Fuji, IX). Similar results were found when assessing the behavior of Vidrion, R and Vidrion, RCaps with regards to cervical microleakage: smaller values presented by the mechanically mixed GIC (Vidrion, RCaps) if compared to the manually mixed one (Vidrion, R), with statistically significant differences (p=0.000) (Table 4).

DISCUSSION

Assuming the fact that the main intrinsic features of an effective restorative material related to a good marginal sealing are its adhesion capacity to the tooth structure and its dimensional stability, and that the conventional GICs present chemical adhesion to the tooth,[20,21] low linear thermal expansion coefficient, similar to the dental structure[20,22] and small setting shrinkage,[21,23] it would be expected to avoid microleakage and all its consequences.

Nevertheless, in this work, very high cervical microleakage indexes were found to all conventional GICs assessed, with 68% of the total samples presenting maximum score (score 3), 22% presenting some microleakage (scores 1 and 2) and only 10% of the samples were leakage free. The great majority of the papers in the related literature also reveal high cervical leakage indexes related to conventional GICs, both in permanent[19,23-25] and primary[3,26] teeth. A few authors, though, verified a great marginal sealing with conventional GICs in permanent[22] and primary teeth. But the lack of detailed methodological information makes it hard to conclusively assess the reasons why those authors obtained such good results.

It is interesting to mention that Alpersatein *et al*.[24] and Yap *et al*.[19] have demonstrated in their papers great microleakage in GIC restorations, even when the samples were not submitted to thermo cycling, which is known for increasing the microleakage values. This fact raises the question about which other factors, beyond adhesive capacity, thermal expansion coefficient and set shrinkage, would count for a good initial marginal sealing.

Despite the GIC's lack of capacity to avoid microleakage in the in vitro tooth / restoration interface, the material may present a good performance in clinical situations due to its fluoride releasing capacity, able to postpone or prevent the development of secondary carious lesions, which represent the real clinical threat of the microleakage.[27]

Heys and Fitzgerald[28] have considered that, as the in vitro assays present dye penetration in GIC restorations but the in vivo ones did not detect bacteria under those same restorations, either the gap between the dentin and the GIC was to small for the bacteria and their byproducts but big enough to allow the dye penetration, or the bacteriostatic/bactericide properties of the material were suffice to prevent the penetration of viable bacteria. Arcoria *et al*.[21] have reported that the methylene blue dye molecule is much smaller than 0.5 mm, which would be the space needed to permit the passage of bacteria and their products through the dentin/restoration interface. Therefore, the dye penetration is not an absolute indicator of what could take place in a clinical context, overestimating the results in many occasions.

The fact that 68% of restorations with GIC presented severe leakage in this in vitro study does not mean that 68% of restorations with this material would fail in clinical situations. Some authors found good indices of success for class II restorations with conventional GIC in primary molars after 2 years (93% by Rutar *et al*., 2000[29] 88.9% - 94.3% depending on the criteria by Honkala *et al*., 200330), after 3 years (81% by Hübel and Mejàre, 200331), and even over 5 years (33% by Kilpatric, 199332). Research can be encouraging once GIC provides a means of restoring primary molars with minimal amount of destruction of sound tooth tissue and reduce treatment time in young patient. The local fluoride release presents also a potential advantage in pediatric dentistry when the quality of the restoration is often damaged by unsuitable children's behavior. The fact that primary teeth have a limited life span also reduces demands on wear resistance, which remains a setback for GIC. Microleakage is a dynamic process that may increase or decrease with time. It is well known that a few clinical events may enhance it (such as successive dimensional changes of the material caused by sudden temperature changes, mechanic occlusal stress, hygroscopic alterations and also by the disintegration of the material in the mouth) whilst others may decrease it (such as the maturation of the restorative material or prolonged exposure to saliva, causing obliteration of the space between the tooth and the restorative material through the deposition of mineral salts and chemically alteration of the dentin composition making it less permeable) on a long term basis.[25,33] A few strategies can be used in order to simulate this microleakage events in vitro and, when under a very straight control, they might really mimic what happens in the mouth. Nevertheless, it was decided not to adopt any of the simulating strategies in this study. On the opposite, it was tried to control at maximum all variables aiming only the appreciation of the effects of the mixing methods on the GIC leakage. Further on, it is intended to include other factors that are known to be equally relevant.

According to Nomoto and McCabe,[15] the mixing technique may alter significantly the final properties of the GIC. Generally speaking, improved properties of the encapsulated GIC have been observed when compared to the separate bottle ones, especially with regards to fluoride release,[11,16,17] setting time,[13] porosity presence,[18] compressive strength[15] and traction resistance.[14]

On the other hand, Gee and Pearson[12] have called the attention to the fact that the compressive strength verified in their study performed with two encapsulated GIC (Opusfil, and Chemfil,) was less than the compressive strength previously reported in the manual mixing correspondents. This result was related to changes in the material composition so that an adequate capsular mixing could be viable.

Indeed, manufacturers perform a few changes in chemical composition of the GICs in order to adapt the material to the capsulated system. Formulae differences, in size and particle distribution and in powder liquid proportion between the bottle and the capsule versions are neither determined nor reported by the manufacturers, disturbing the analysis of the results of researches that compare the mixing methods.[12,14-16]

In this experiment, the mixing effects on cervical microleakage were assessed in Class II restorations of extracted primary molar teeth. Two conventional GICs used in ART were assessed, presenting two different versions on the same brand (Vidrion, R / Vidrion, RCaps and Fuji, IX/Fuji, IXGPFAST). A significantly high difference was observed (p=0.000) in cervical microleakage values between manual and mechanical mixing methods. The last one presenting the lower scores, regardless of the material used, considered as something that should be expected according to the literature. Many papers have assessed microleakage on both manually and encapsulated conventional GIC, but only one has compared the mixing methods. Cooley and Train[34] reported that the mixing method did not bear any significant influence in microleakage when studying class V restorations performed on permanent molars. The study used conventional encapsulated GIC (Ketac-Fil, and Fuji, Cap II) and their correspondent bottled versions (Chelon-Fil, and Fuji, II). Nonetheless, the authors noticed a certain trend in mechanically mixed GIC to present lower microleakage values.

The well adapted and well marginally sealed restorations are essential to a well succeeded ART, considering the fact that isolating the external media is very important to create the proper conditions for the organism to fight remaining bacterial infection in the dentinal tissue at the bottom of the cavity, and also to remineralize the local dental structure.

The scarce standardization existing between the methodologies used to the *in vitro* assessment of microleakage and the defective reports of the variables impair a more conclusive confrontation of the results of these studies.

Despite the many attempts to standardize experimental conditions so that influences of the mixing method were better perceived in this work, it is difficult to ignore that other variables besides the mixing method (such as chemical composition changes between encapsulated and bottled materials and also differences in insertion methods) could bear impact on the final results.

The researchers involved in this work have chosen to follow manufacturer's instructions. Since the Vidrion, R directions did not describe a specific way of insertion of the material into the cavity, this procedure was standardized to both manually mixed GICs according to the recommendations described by Fuji, IX manufacturers, which suggests the use of a blunt instrument. The encapsulated Fuji, IXGPFAST was inserted into the cavity with the capsule tip itself and Vidrion, RCaps, lacking the capsule tip that allows the material direct extrusion into the prep, was inserted with the aid of a Centrix, syringe, in an attempt to obtain an approximation of the restorative conditions between GICs of the same mixing method.

Although the manually mixed GICs were carefully inserted, adapted and subsequently packed, in order to obtain the best adaptation at the bottom of the cavity, it is likely that the insertion method may have influenced the achievement of better results with the mechanically mixed materials. The use of an insertion syringe or capsules adapted to the same function may decrease the microleakage, once they allow a precise adaptation of the cement at the bottom of the prep.[2,23] Therefore, it would worth the effort to perform further studies comparing mixing methods, with the aid of the Centrix, device also used to insert the manually mixed GICs.

The best performance material was Vidrion, RCaps. However, this group presented great variation: 30% of the specimens with severe microleakeage and the rest being acceptable (table 2). Vidrion® RCaps is an alternative conventional restorative GIC to those GICs with high powder/liquid proportion. It is much more financially accessible than Fuji® IX or Fuji® IXGPFastcapsule, making possible its wide use in public health both for ART applications and conventional restorative treatment what is interesting considering the great demand for dental treatment in development countries such as Brazil. However, although Vidrion® RCaps is cheaper, it could present some disadvantages. For example, its capsule features. Vidrion® RCaps capsule has inferior quality with regard to shape and location of the sealing wax that separates the liquid from the powder. These factors may influence the effective contact between powder and liquid, as well as the extension of the mixture and, consequently, the final properties of the material, including microleakage. In this research, when the Vidrion® RCaps capsule was opened for the removal of GIC after the mixing in agreement with the manufacturer's instructions, sometimes it was possible to observe powder out of the mixed material and it could be a possible explanation for the great variation of microleakage in this group. However, we must consider that the related literature also reveal great variation for in vitro microleakage studies.[23,26,34-36]

It also would be interesting that the scientifically proved advantages of the encapsulated GICs became an incentive to the use of this modality, expanding its use and lowering its cost, making it accessible to general clinicians, both for the modified ART application and the conventional restorative treatment.

REFERENCES

1. Sepet E, Aytepe Z, Guven Y. Artificially formed caries-like lesions around Class II glass ionomer restorations in primary molars. J Clin Pediatr Dent 20: 37-40, 1995.
2. Morabito A, Defabianis P. The marginal seal of various restorative materials in primary molars. J Clin Pediatr Dent 22: 51-54, 1997.
3. Virmani S, Tandon S, Rao N. Cuspal fracture resistence and microleakage of glass ionomer cements in primary molars. J Clin Pediatr Dent 22: 55-58, 1997.
4. Frencken JE, Holmgren CJ. How effective is ART in the management of dental caries? Community Dent Oral Epidemiol 27: 423-430, 1999.
5. Frencken JE, Makoni F, Sithole WD. ART restorations and glass ionomer sealants in Zimbabwe: survival after 3 years. Community Dent Oral Epidemiol 26: 372-381, 1998.
6. Mallow PK, Durward CS, Klaipo M. Restoration of permanent teeth in young rural children in Cambodia using theatraumatic restorative treatment (ART) technique and Fuji II glass ionomer cement. Int J Paediatr Dent 8: 35-40, 1998.
7. Ho TFT, Smales RJ, Fang DTS. A 2 year clinical study of two glass ionomer cements used in the atraumatic restorative treatment (ART) technique. Community Dent Oral Epidemiol 27: 195-201, 1999.
8. Wong MC, Schwarz E, Lo ECM. Patterns of dental caries severity in Chinese kindergarten children. Community Dent Oral Epidemiol 25: 343-347, 1997.
9. Lo ECM, Holmgren CJ. Provision of atraumatic restorative treatment (ART) in restorations to Chinese pre-school children – a 30 month evaluation. Int J Paediatr Dent 11: 3-10, 2001.
10. Yip HK, Smales RJ, Yu C, Gao XJ, Deng DM. Comparison of atraumatic restorative treatment and conventional cavity preparations for glass-ionomer restorations in primary molars: one-year results. Quintessence Int 33: 17-21, 2002.
11. Verbeeck RMH, DeMoor RJG, VanEven DFJ, Martens LC. The short-term fluoride release of a hand-mixed vs. capsulated systems of a restorative glass-ionomer cement. J Dent Res 72: 577-581, 1993.
12. Gee D, Pearson GJ. Effect of mixing speed on mechanical properties of encapsulated glass-ionomer cements. Br Dent J 174: 65-68, 1993.
13. Kilpatrick NM, McCabe JF, Murray JJ. Factors that influence the setting characteristics of encapsulated glass ionomer cements. J Dent 22: 182-187, 1994.
14. Mitchell CA, Orr JF, Russel MD. Capsulated versus hand-mixed glass-ionomer luting cements for post retention. J Dent 26: 47-51, 1998.
15. Nomoto R, McCabe JF. Effect of mixing methods on the compressive strength of glass ionomer cements. J Dent 29: 205-210, 2001.
16. Brooks ES, Miller BH, Nakagima H, Guo I. Manipulation effects on fluoride release from chemically-cured and resin-modified glass ionomers. Am J Dent 10: 120-122, 1997.
17. Miller BH, Komatsu H, Nakajima H, Okabe T. Effect of glass ionomer manipulation on early fluoride release. Am J Dent 8: 182-186, 1995.
18. Mitchell CA, Douglas WH. Comparison of the porosity of hand-mixed and capsulated glass-ionomer luting cements. Biomaterials 18: 1127-1131, 1997.
19. Yap AUJ, Tan S, Teh TY. The effect of polishing systems on microleakage of tooth coloured restoratives: Part 1. Conven-

cional and resin-modified glass-ionomer cements. J Oral Rehabil 27: 117-123, 2000.
20. McLean JW, Wilson AD. The clinical development of glass-ionomer cements: Formulation and properties. Aust Dent J 22: 31-36, 1977.
21. Arcoria CJ, Vitasek BA, DeWald JP, Wagner MJ. Microleakage in restorations with glass ionomer liners after thermocycling. J Dent 18: 107-112, 1990.
22. Bullard RH, Leifelder KF, Russel CM. Effect of coefficient of thermal expansion on microleakage. J Am Dent Assoc 116: 871-874, 1988.
23. Scherer W, Kaim J, Gottlieb-Schein E, Roffe-Bauer, M. Microleakage of capsulated glass ionomer cements. Am J Dent 2: 355-357, 1989.
24. Alperstein KS, Graver HT, Herold RC. Marginal leakage of glass-ionomer cement restorations. J Prosthet Dent 50: 803-807, 1983.
25. Bouschlicher MR, Vargas MA, Denehy GE. Effect of desiccation on microleakage of five Class 5 restorative materials. Oper Dent 21: 90-95, 1996.
26. Fuks AB, Holan G, Simon H, Lewinstein I. Microleakage of-class 2 glass-ionomer-silver restorations in primary molars. Oper Dent 17: 62-69, 1992.
27. Triadan H. When is microleakage a real clinical problem? Oper Dent 12: 153-157, 1987.
28. Heys RJ, Fitzgerald M. Microleakage of three cement bases. J Dent Res 70: 55-58, 1991.
29. Rutar J, McAllan L, Tyas MJ. Clinical evaluation of glass ionomer cement in primary molars. Pediatr Dent 22: 486-488, 2000.
30. Honkala E, Behbehami J, Ibricevic H, Kerosuo E, Al-Jame G. The atraumatic restorative treatment (ART) approach to restoring primary teeth in a standard dental clinic. Int J Paediatr Dent 13: 172-9, 2003.
31. Hübel S, Mejàre I. Cenventional versus resin-modified glass-ionomer cement for Class II restorations in primary molars. A 3-year clinical study. Int J Paediatr Dent 13: 2-8, 2003.
32. Kilpatrick NM. Durability of restorations in primary molars. J Dent 21: 67-73, 1993.
33. Going RE. Microleakage around dental restorations: a summarizing review. J Am Dent Assoc 84: 1349-1357, 1972.
34. Cooley RL, Train TE. Comparison of manually and mechanically mixed glass ionomers. J Prosthet Dent 66: 773-776, 1991.
35. Zyskind D, Frenkel A, Fuks A, Hirschfeld Z. Marginal leakage around V-shaped cavities restored with glass-ionomer cements: an in vitro study. Quintessence Int 22: 41-5, 1991.
36. Alonso RCB, Sinhoreti MAC, Correr Sobrinho L, Consani S, Goes MF. Effect of resin liners on the microleakage of class V dental composite restorations. J Appl Oral Sci 12: 56-61, 2004.